TROPOSPHERIC PHASE STRUCTURE FUNCTIONS FROM SPACECRAFT DOPPLER TRACKING

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We have measured temporal radiowave phase structure functions for time lags 10-100 seconds using Doppler tracking data of the Mars Observer spacecraft. These X-band observations were made for 19 days in March-April 1993 using 34-m antennas at the three NASA/JPI, Deep Space Network tracking complexes (California, Spain, Australia). Elevation angles ranged from 17 to 74 degrees; hydrogen maser frequency standards controlled the transmitter and receiver. The observations were made in the "two-way" tracking mode (transmitted signal coherently transponded back to earth), which allows us to distinguish propagation and instrumental noises based on their differing transfer functions to the observable. Data were taken when Mars Observer was in interplanetary cruise with a sun-earth-spacecraft angle of about 100 degrees and an earth-spacecraft distance of about 500 light seconds,

After removing systematic effects due to spacecraft trajectory and motion of the spacecraft antenna relative to center-of-mass, we obtained residual Doppler frequency time series. These frequency residuals were integrated to produce phase time series from which structure functions were calculated. The structure functions thus obtained were approximated by power-laws, $D(\tau) = const\,\tau^{\alpha}$. We characterize $D(\tau)$ by its level at $\tau = 100$ seconds and its powerlaw index, α, measured between 30 and 100 seconds.

Powerlaw indicies varied between 0.67 and 1.6, averaging 1.2. The lower envelope of a plot of structure function level versus elevation angle showed a weak elevation angle dependence, but large positive excursions were observed. Any dependence on local time between about 1600-0300 hours was weak. A histogram of structure function level shows more relatively low values and fewer relatively large values. There were small systematic variations in the structure function level between the sites, with the Australian site having larger levels in our sample. Assuming frozen flow, our structure function levels can be compared with spatial measurements made at the VLA (R. A. Sramek, "Atmospheric Phase Stability at the VLA", URSI/IAU Symposium on Radio Astronomical Seeing, Beijing, 1989). We found the median inferred rms path delay (averaged over all sites and converted to a spatial separation of 1km using an assumed 5 m/sec transverse wind speed) to be about 3 times larger than the median of the VLA summer night rms path delays. We discuss some implications for precision Doppler tracking observations, particularly as they refine the noise model for low-frequency gravitational wave searches.